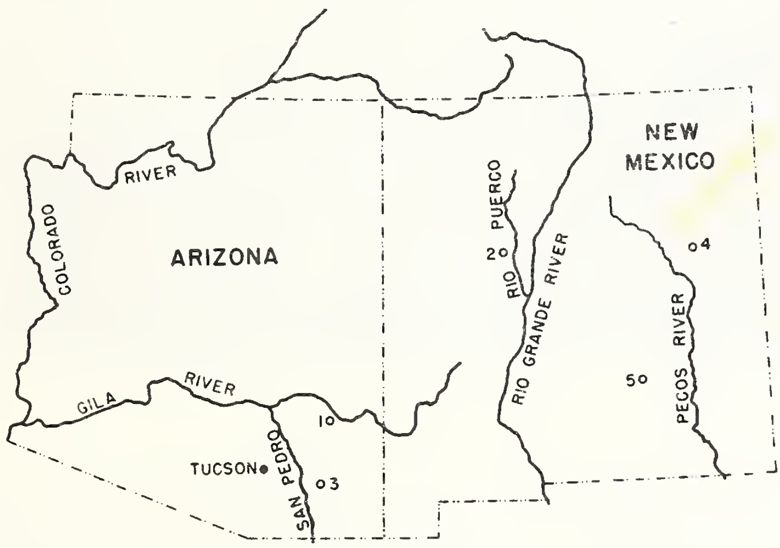
WALNUT GULCH EXPERIMENTAL WATERSHED

AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

IN COOPERATION WITH
U. S. SOIL CONSERVATION SERVICE,
UNIVERSITY OF ARIZONA
AND LOCAL RANCHERS

SOUTHWEST WATERSHED RESEARCH CENTER

Studies on the Walnut Gulch watershed are part of a comprehensive research program to: (1) determine the future water yield potential of semiarid rangeland watersheds in the Southwest, as related to measures for their conservation and sustained production of forage; (2) determine optimum utilization of water yield, for local and downstream uses; and (3) obtain information needed for the planning and design of measures for flash flood and sediment damage control.



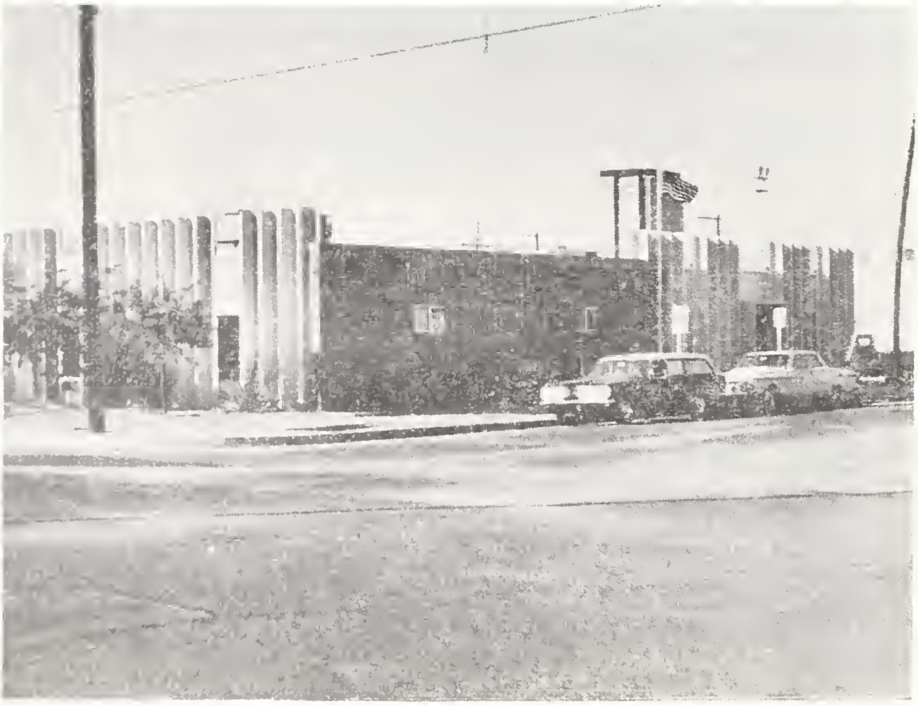
1. Safford, Arizona
2. Albuquerque, New Mexico
3. Walnut Gulch near Tombstone, Arizona
4. Alamogordo Creek near Santa Rosa, New Mexico
5. Fort Stanton, New Mexico

Location of Experimental Watersheds.

This research was initiated by the former Research Division of the Soil Conservation Service, at the request of its Operations Division. After screening a large number of prospective areas in Arizona, New Mexico, and Colorado, active research was begun in 1953 on the Walnut Gulch area, and in 1954 on the Alamogordo Creek area near Santa Rosa, New Mexico. In a reorganization of the U. S. Department of Agriculture in 1954, the research work and personnel were transferred from the Soil Conservation Service to the newly formed Agricultural Research Service; and in 1961, the Southwest Watershed Research Center* was established to carry on this work, with headquarters at Tucson.

* Southwest Watershed Research Center, Agricultural Research Service, USDA, 442 East Seventh Street, Tucson, Arizona 85705.

Walnut Gulch watershed. The Dragoon Mountains are in the background and the city of Tombstone in the foreground. Extreme upper end of watershed lies below gap in mountains at right. Quonset buildings in the right center are the field office and shops.



The headquarters of the Southwest Watershed Research Center in Tucson contains laboratories for water, sediment, and soil analysis and has facilities for processing all research data.

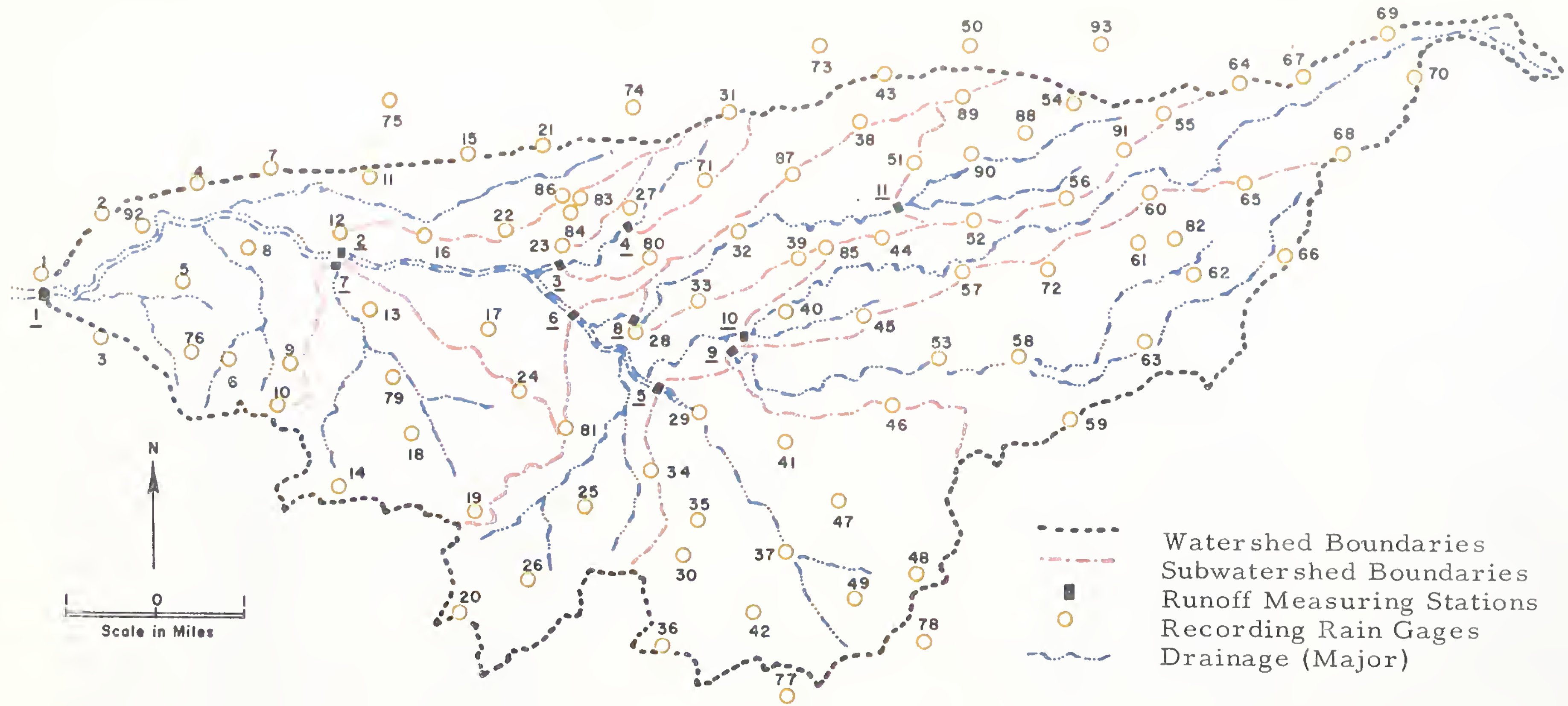
The research is being conducted in cooperation with the Arizona and New Mexico Agricultural Experiment Stations, the Soil Conservation Service, the local Soil Conservation Districts, and the ranchers who own the land or hold grazing leases on public lands in the watersheds. Less extensive work is being done on several small drainage areas near Safford, Arizona, and Albuquerque, New Mexico, where runoff and precipitation data have been collected since 1939 and since 1965 on three small drainage areas near Fort Stanton, New Mexico.

The research objectives are being realized in two stages, which may be pursued simultaneously. The first stage is the identification of the factors operating in the hydrologic system under observation. The second involves the research stage, during which range improvement practices and other experiments are applied to the watershed.

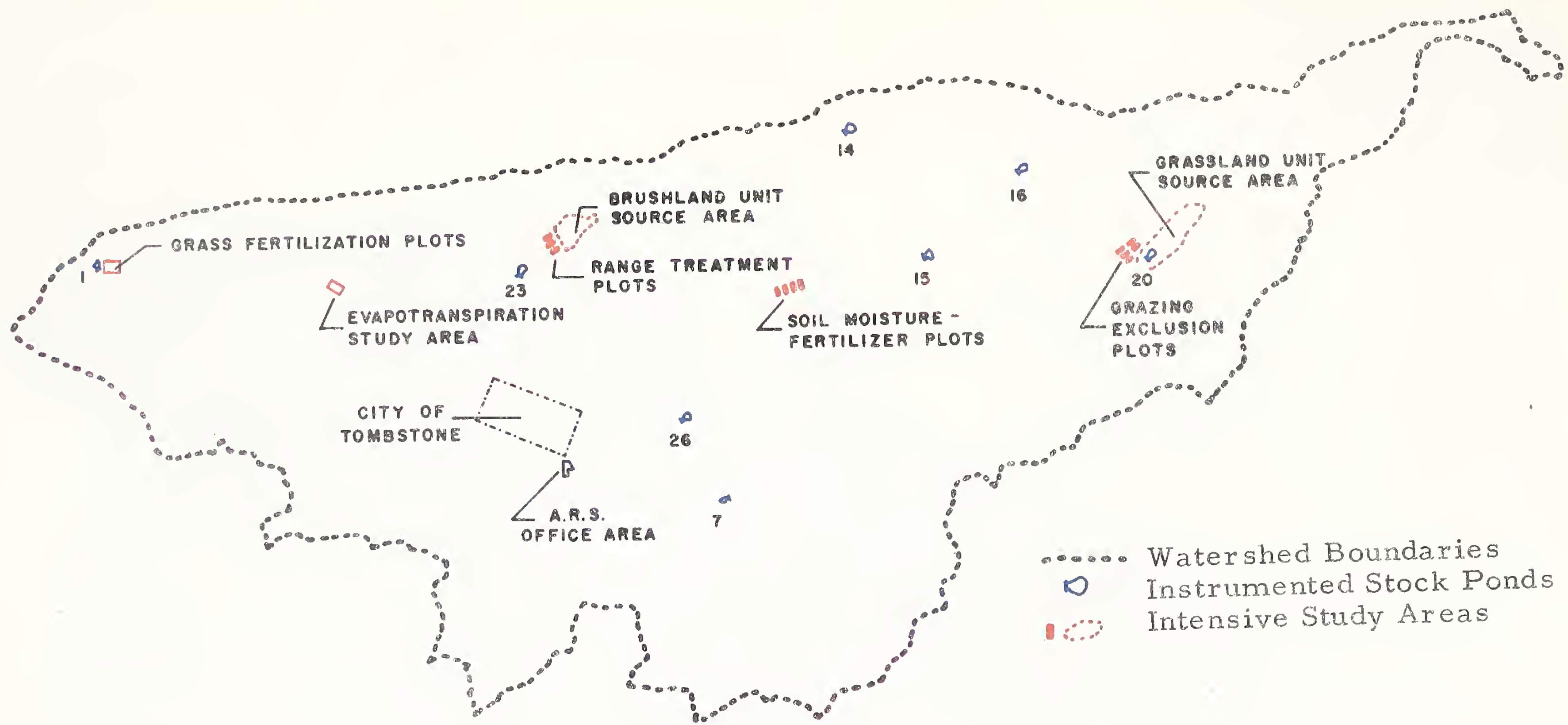
The identification is begun by making accurate measurements of rainfall, runoff, sediment movement, soil, vegetation, geology, and other parameters. These measurements are continued long enough to have a sampling of the hydrologic variability which occurs. Such sampling will provide information to test and select good conceptual and mathematical models for use in the second stage of the work. During the second stage, various experiments, such as water management, range improvement, erosion control, etc. are conducted. The results of these experiments will be evaluated and recommendations will be made concerning water and land use in the semiarid Southwest for the improvement of personal and public welfare.

WALNUT GULCH EXPERIMENTAL WATERSHED

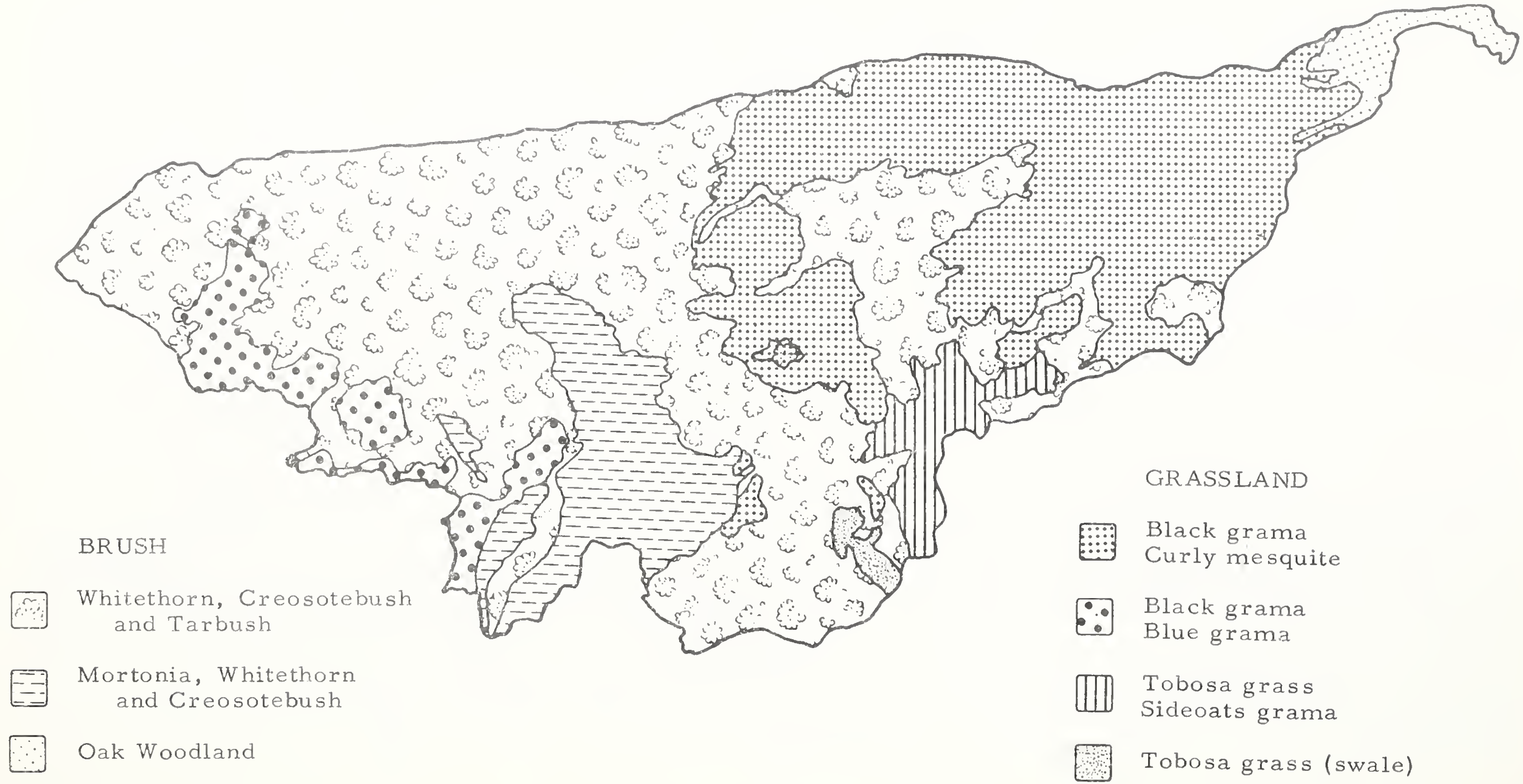
Walnut Gulch is an ephemeral tributary of the San Pedro River, having their confluence near Fairbank, Arizona. The study area comprises the upper 58 square miles of the Walnut Gulch drainage basin. The watershed is a high foothill alluvial fan with materials ranging from clays and silts to well-cemented boulder conglomerates with little continuity of bedding. The topographic expression is that of gently rolling hills incised by a youthful drainage system. The area is representative of mixed grass-brush rangelands of southeastern Arizona and southwestern New Mexico. Altitudes above mean sea level range from 4,200 feet at the lowest gaging station to 6,000 feet at the upper end. Nearly all of the streamflow occurs between July and early October, and results from intense, convective thunderstorms. During an average year, five to ten flows pass most of the gaging stations with the channel being dry about 99 percent of the time.



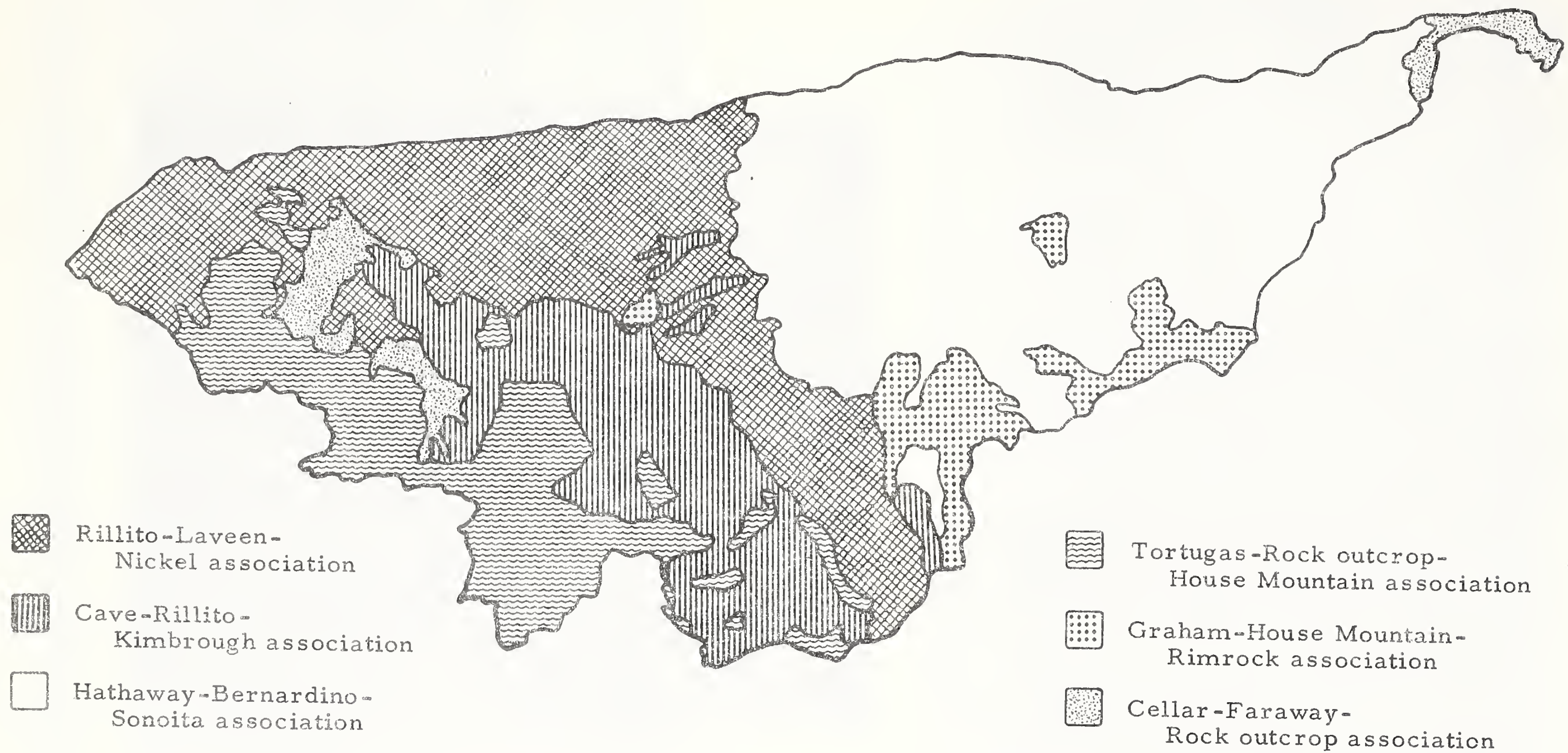
Drainage Map showing hydrologic measuring installations.



Intensive study areas on Walnut Gulch watershed.



Vegetation Map

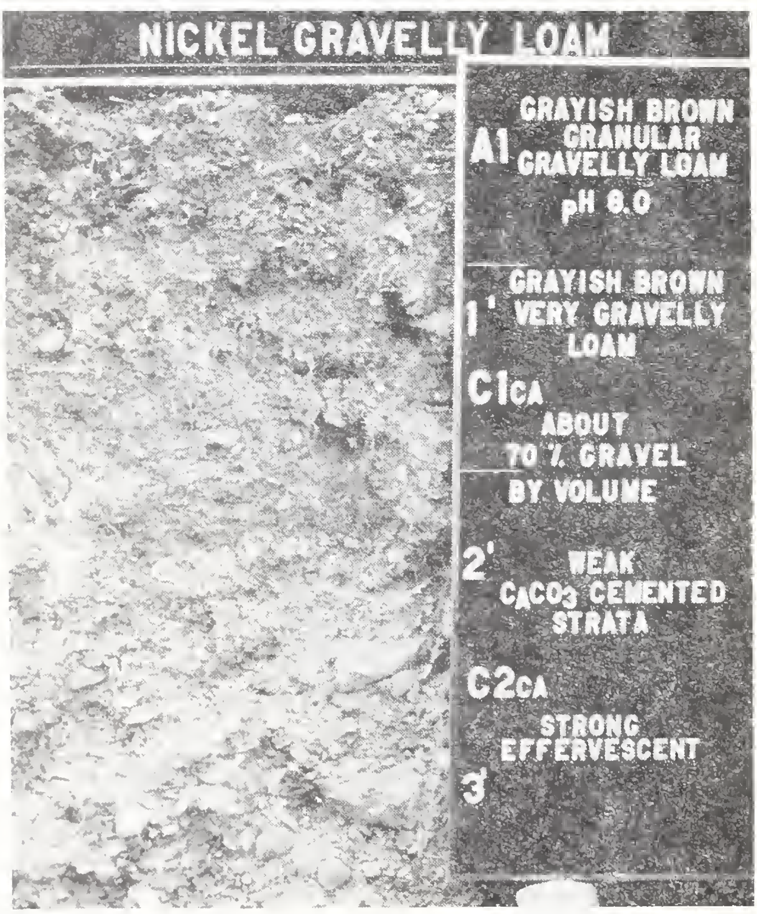


Rillito-Laveen-
Nickel association
Cave-Rillito-
Kimbrough association
Hathaway-Bernardino-
Sonoita association
Tortugas-Rock outcrop-
House Mountain association
Graham-House Mountain-
Rimrock association
Cellar-Faraway-
Rock outcrop association

Soils Map

VEGETATION AND SOILS

The vegetation and soils of the area have been surveyed and mapped. Vegetation on approximately two-thirds of the area is predominately shrubs with varying amounts of grass; that of the remaining third is predominately grass. Major shrubs are whitethorn, creosotebush, tarbush, and mortonia; most prevalent grasses are black grama, curly mesquite grass, tobosa grass, and slim tridens. Although cover of grasses and shrubs, as well as that of certain individual species is correlated in varying degree with soil series and with some of their physical and chemical characteristics, distribution of but one major species -- mortonia -- is sharply limited to particular soils. Mortonia is limited to three soil series underlain by solidified caliche. The most striking correlation of plant cover is that with distance from the town of Tombstone; as this distance increases, total grass cover increases, and total shrub cover decreases. This lends credence to the hypothesis that grass cover has diminished, and shrub cover has increased since settlement of the town about 1880, as a result of varying intensity of grazing during the early mining period in and immediately adjacent to the town.



A soil profile showing the shallowness and gravelly texture of the soil commonly occurring on the watershed.

Herein 1905, according to one of the early ranchers, there was not "a bush big enough for a calf to hide behind."

Response of grass cover to degree of use. The area to the left of fence had been heavily grazed for many years; that to the right had received moderate use.

GEOLOGY

Walnut Gulch watershed is a high foothill alluvial fan portion of the larger San Pedro River watershed. The Cenozoic alluvium is very deep and is composed of coarse-grained fragmentary material, the origin of which is readily traceable to present-day mountains on the flank of the watershed. The alluvium consists of clastic materials ranging from clays and silts to well-cemented boulder conglomerates with little continuity of bedding. This alluvial fill material is known to be over 1,200 feet deep in places and serves as a huge reservoir for ground water. The topographic expression is that of gently rolling hills incised by a youthful drainage system.

The rolling alluvial hills in the foreground are typical of those found in the upper portion of the watershed.

The remaining mountainous portion of the watershed consists of rock types ranging in age from pre-Cambrian to Quaternary, with a rather complete geologic section. Rock types range from ridge-forming limestone to weathered granite intrusions. The geologic structural picture of the mountainous area is complex, with much folding and faulting. This folding and faulting, along with igneous intrusions has resulted in large areas of shattered rock, which tend to greatly affect the hydrology.

A fault-aligned stream channel. The steep flat cliff face on left is a fault scarp.

The hydrology of the watershed is, in places, controlled by past geologic events and structures. Intrusive igneous dikes in the Tombstone Hills influence ground water movement, as well as change the surface drainage. The Schieffelin granodiorite alters the course of the main stream of Walnut Gulch, acts as a probable groundwater barrier between the abundant waters in the Tombstone Hills and the deep alluvial basin, and causes numerous small perched water tables along its perimeter. Highly compacted conglomerate beds greatly alter the path of stream channels and, in places, divert streams at more than right angles. High angle faults form new paths for streamflow, making channels arrow-straight in some places and causing diversions in others.

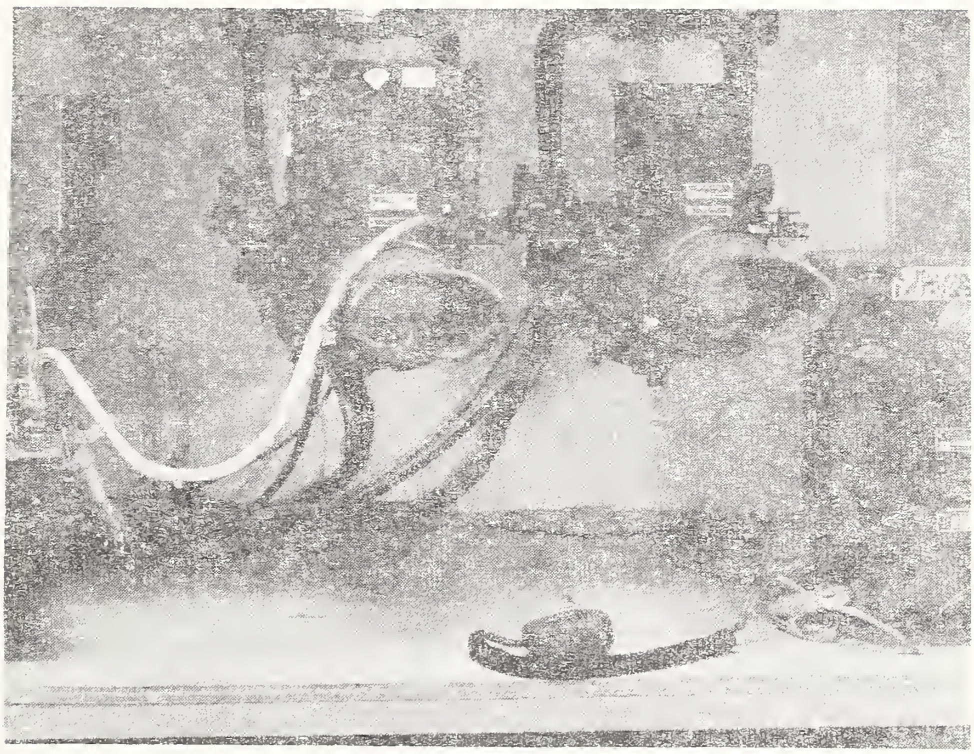
PRECIPITATION

Annual precipitation since 1904 at Tombstone has averaged 14.5 inches, and has varied from 7.36 inches in 1924 to 27.84 inches in 1905. Similar, although less pronounced variation, has been observed in a single year among the network of rain gages we are maintaining on the watershed. The average annual rainfall over the entire 58-square-mile watershed has varied from 7.1 to 14.2 inches with a mean for the 1955-1966 period of 11.3 inches.

The typical thunderstorm curtain centered in the picture covers only a small portion of the watershed area.

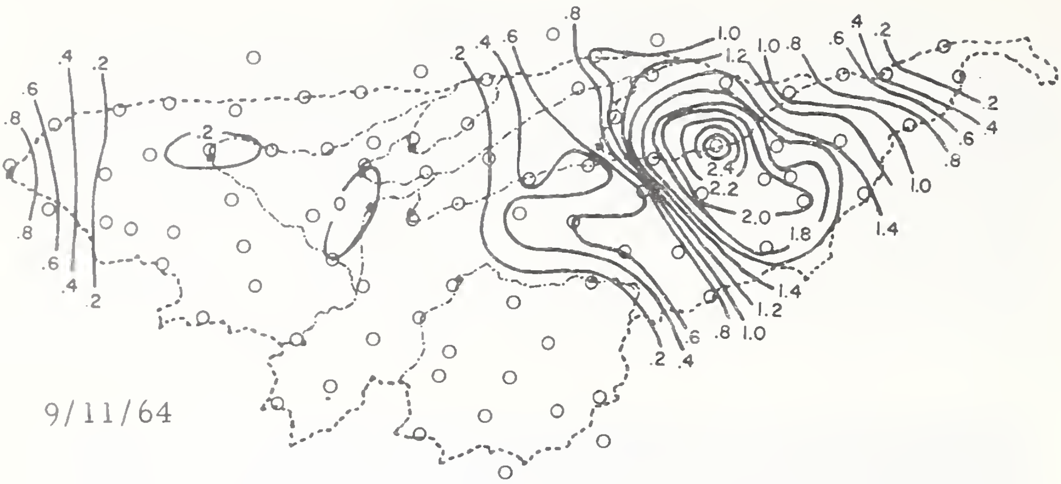
The year's precipitation falls during two distinct periods, with greatly differing characteristics. Winter precipitation, amounting to one-third of the annual total, occurs as snow or rain of wide extent and low intensity. We have never recorded runoff from winter storms except on very small areas. Most of the remaining two-thirds of the precipitation falls during July, August, and September as intense convective thunderstorms of small diameter. Practically all runoff results from this type of storm. Of the runoff-producing portions of these summer storms, 80 percent have been observed to cover 4.5 square miles or less within the confines of the Walnut Gulch watershed; however, this included some storms falling on the edge of the area, with portions of their extent not measured.

Intense storms of this sort have important effects on the runoff pattern of the watershed. Consequently, adequate records of their distribution, amount, and intensity are indispensable; hence, the dense network of 94 recording gages on, or adjacent to, the 58-square-mile study area.

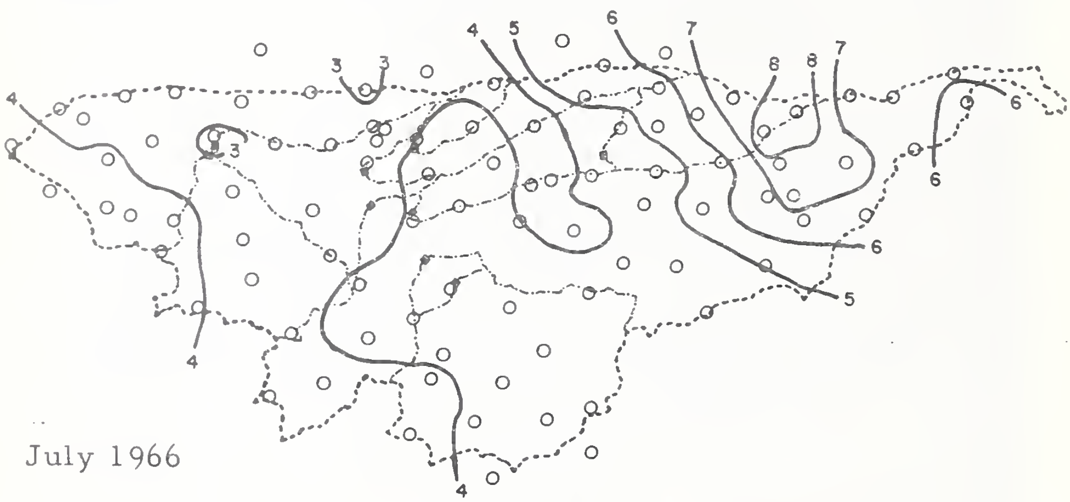


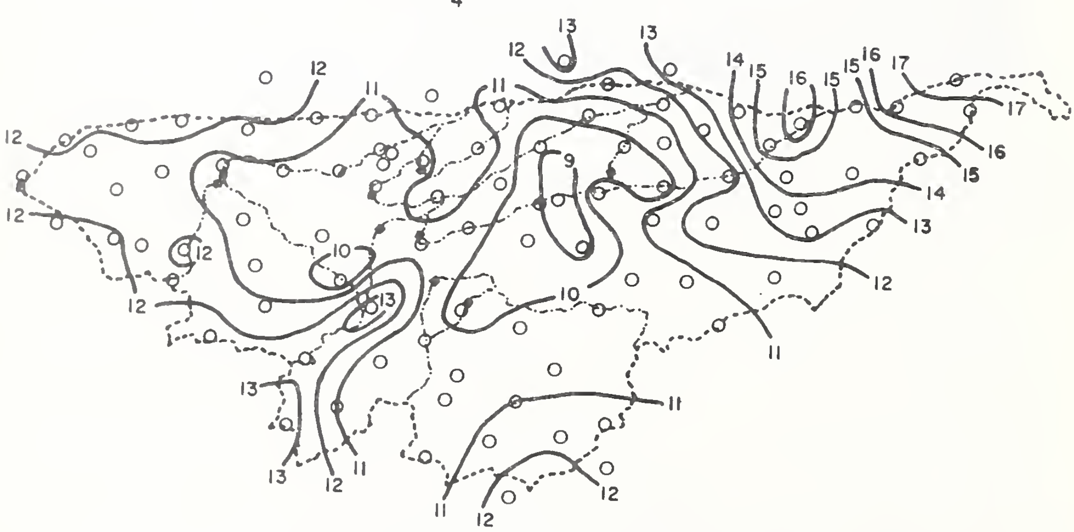
Radar equipment in the field office enables technicians to be forewarned to collect sediment samples from flooding streams as soon as runoff begins.

Radar equipment is used to observe the location and movement of small thunderstorms while they are occurring. Two-way radio contact between the field office, where the radar set is located, and observers in the field help to deploy the crews to strategic locations at the right time to make necessary measurements during flows and to collect the desired sediment samples.



Isohyetal map shows rainfall distributions on the watershed for a typical summer thunderstorm. The runoff-producing portion of the rainfall covered only a portion of the watershed.





Summer 1966

Summer rainfall variability is great and has been found to occur randomly for both individual storms and seasonal totals. The dense rain gage network describes the distribution, amount, and intensity of the storms.

ON-SITE RUNOFF

Relation of on-site runoff and sediment production to characteristics of soils and vegetation is under study on 6- x 12-foot plots receiving different treatments or no treatment. The treatments include brush removal, soil pitting, and reseeding to grass -- alone and in combination -- on one set of plots. Those of another set receive fertilizer and are sprinkled to alter soil moisture. Records of soil moisture, rainfall, and runoff are kept for all the plots. The amounts of runoff from the plots receiving the different treatments are compared.

Results of infiltrometer studies on these and similar plots indicate that average runoff decreases with an increase in crown spread of vegetation, amount of pebbles on the soil surface, and number of plants per plot. In simple correlations, antecedent soil moisture was never related significantly to runoff.

Sediment production appears to be greatly affected by differences in basal cover of grasses, and is much higher on predominantly brush-covered than on predominantly grass-covered watersheds.

Data indicate runoff per unit-area from watersheds of even a few acres is considerably less than from 6- x 12-foot plots and is more dependent on the nature of rainfall than on the type of watershed vegetation. These small plots should furnish information, however, concerning the relation of runoff and sediment production to plant and soil factors and to range practices on larger areas. As the information accumulates, further attempts will be made to extend it to successively larger adjacent areas and, in conjunction with soil and vegetation surveys, to the entire 58-square-mile watershed.

6- x 12-foot brush (upper) and grass (lower) plots on which infiltration measurements are made to determine relationship of vegetation and soil factors to runoff and sediment yield. The white box in the foreground of the grass plot shelters a recorder for measuring intensity of runoff.

UNIT-SOURCE DRAINAGE AREAS

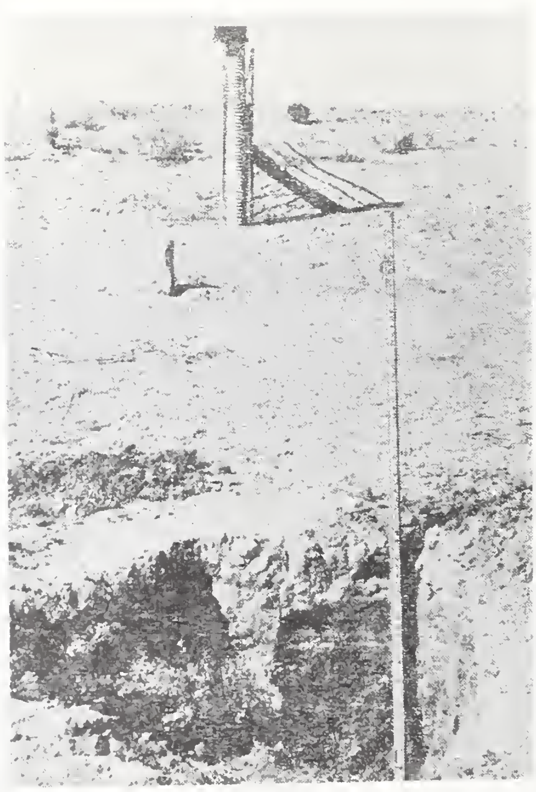
Subwatersheds from 1 to 375 acres with relatively homogeneous soil and vegetation, have been selected as unit-source drainage areas to study runoff and sediment yield. Six dominantly brush-covered areas, varying from 1 to 11 acres, are equipped for measuring runoff. This small size was selected because of the small diameter of runoff-producing storms, as well as differences in soils and vegetation within larger areas. Four of these areas have V-notch weirs, and two are equipped with H-flumes. Eight subwatersheds, ranging from 50 to 375 acres in size, drain into stock ponds, where runoff and sediments are measured. Six of the small areas lie within, or adjacent to, one of the stock pond drainage areas, which is brush covered. After a suitable calibration period, three of these small areas will be subjected to range treatment -- brush removal, seeding, etc. -- and the other three will be left untreated.

Three dominantly grass-covered subwatersheds, of 3, 60, and 120 acres, are equipped with V-notch weirs to measure their runoff. Measurements will be compared with those of the brush-covered areas. Variations in size of watersheds, for both grass- and brush-covered areas, permit evaluation of water losses with respect to size of the drainage areas.

Broad-crested V-notch weir on the 11-acre, shrub-covered Lucky Hills Experimental Subwatershed.

The drainage areas above the stock ponds differ markedly in soils and vegetational cover, and thus afford valuable comparisons. Bennett's Big Tank, for example, built in 1938, catches water from 375 acres of grassland. Its bed, covered with a layer of fine sediment, is relatively impermeable, and the tank usually holds water throughout the year. On the other hand, Lucky Hills Tank, built in 1957, receives water from 117 acres covered mainly with creosotebush, tarbush, and whitethorn. Its bed is of highly calcareous soil and is very permeable. In August 1960, this pond lost three acre-feet of water in nine days.

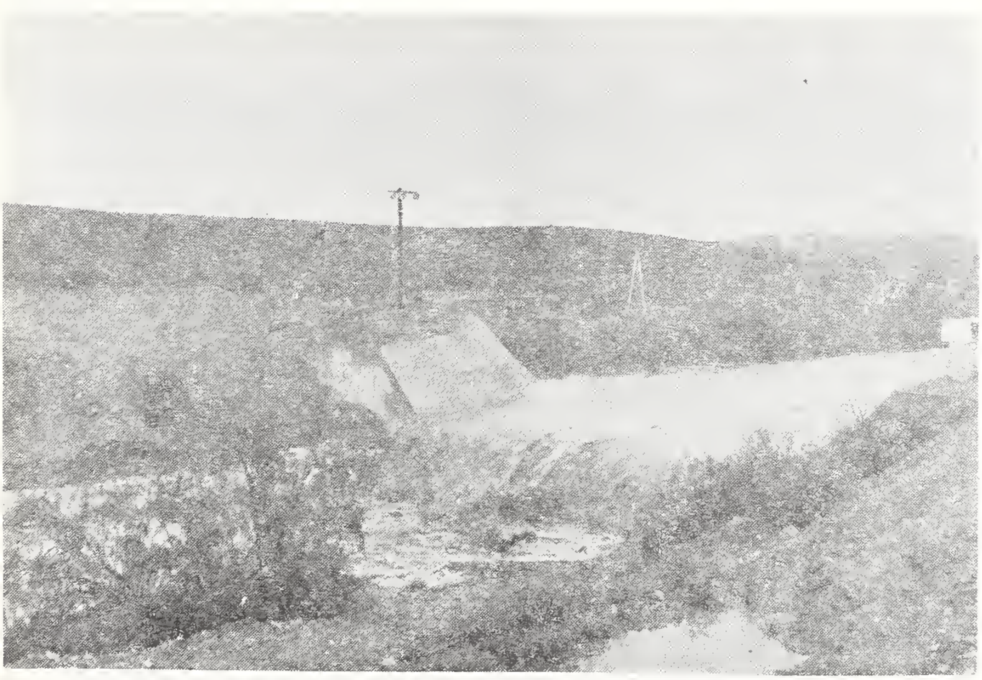
Sediment production, as indicated by accumulation in the ponds, is considerably greater from brush-covered areas than from those covered with grass. This is probably attributable to two factors: Shrub invasion has been greater on the less stable soils, and grass protects the soils surface better than do shrubs. During a four-year period, sediment loss per acre was almost four times as great from the brush-covered Lucky Hills area as it was from the grass-covered Bennett area.



Lucky Hills Tank, although full in late August, was completely dry in mid-November. Its brush-covered drainage area has yielded nearly four times as much sediment as the grass-covered area above the Bennett Big Tank. Almost three feet of sediment has been deposited in eight years.

STREAMFLOW MEASUREMENTS

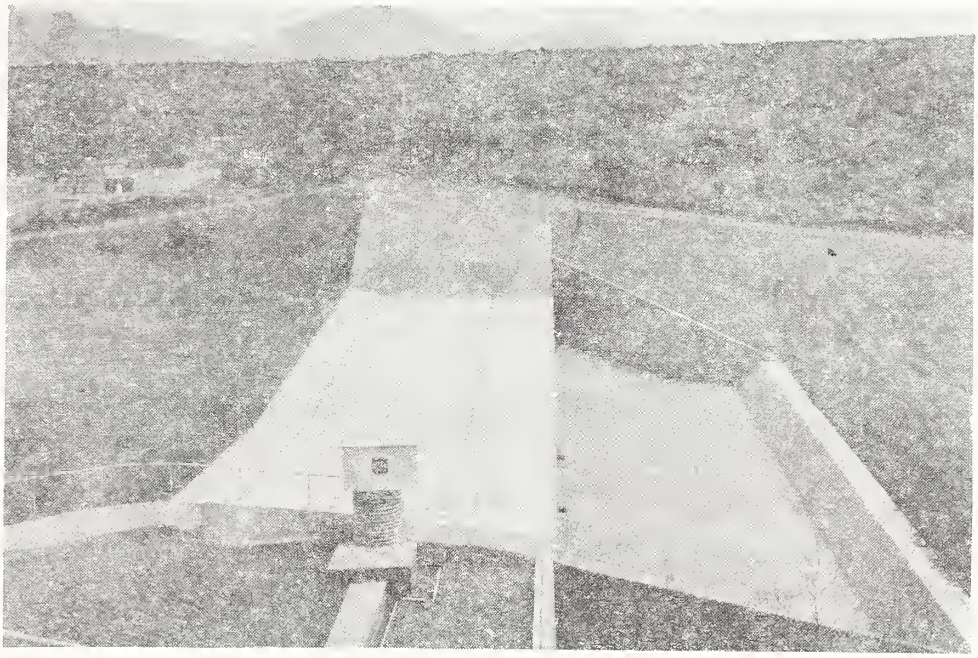
In addition to the measurements being made on the plots and unit-source areas, streamflow is measured from larger heterogeneous subwatersheds at 11 gaging stations, with eight on tributaries and three on the main channel of Walnut Gulch. The measuring structures at these stations are prerated, critical-depth flumes. They were developed cooperatively by staff members of the Southwest Watershed Research Center and the Agricultural Research Service Hydraulics Laboratory at Stillwater, Oklahoma, especially to obtain accurate measurements of the sediment- and debris-laden flows of ephemeral streams. Of the three flumes in the main channel, Flume Number 1, with a capacity of 25,000 cubic feet per second, measures the runoff from the entire 58 square miles; Flume Number 2, with a capacity of 19,500 cubic feet per second, subtends a drainage area of 44 square miles; and Flume Number 6, below an area of 37 square miles, has a capacity of 18,000 cubic feet per second. Flume Number 1 is probably the largest prerated critical depth-flume in the United States.



A flow of 2,000 cu. ft. per second in Flume 6, which has a capacity of 18,000 cu. ft. per second and measures runoff from 37 square miles. The men in the cable car are taking sediment samples.

5:23 p.m. Runoff water entering Flume 2 from thunderstorm occurring 10 miles upstream 2 hours earlier.

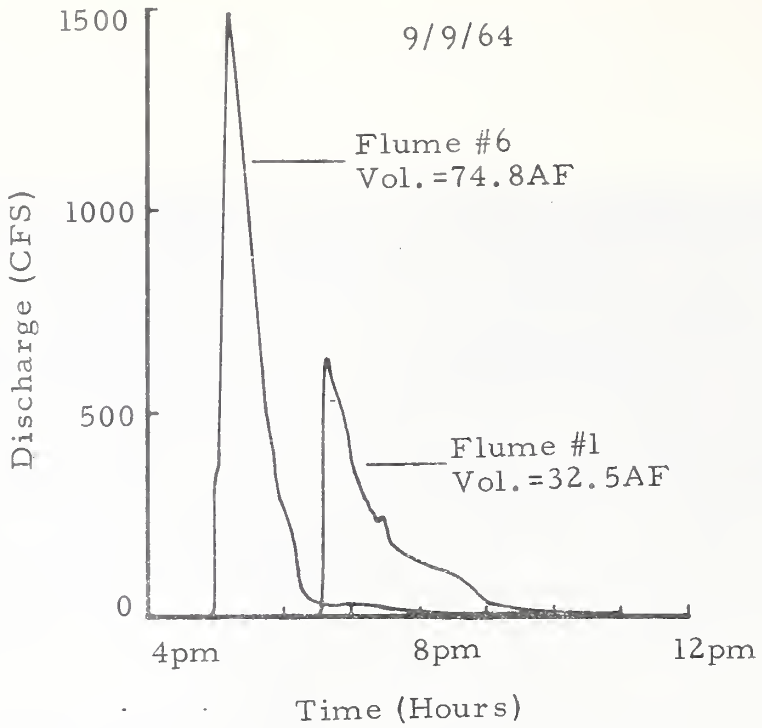
5:30 p.m. Seven minutes later, flash flow has reached peak of 350 cu. ft. per second.



Flume Number 1 from north bank, showing stilling basin. Because of the unstable substructure, this stilling basin was required to prevent scour damage to the flume during high flows.

TRANSMISSION LOSSES AND GROUND WATER RECHARGE

Walnut Gulch is an ephemeral tributary of the San Pedro River. The channel is dry about 99 percent of the time and has a potential to absorb large quantities of runoff. Owing to the small diameter of the runoff-producing storms, most flows traverse dry channels, and large reductions in the runoff occur. These flow absorptions or transmission losses are being measured in Walnut Gulch in several channel portions. The magnitude of the losses for a particular storm event is computed by comparing the runoff hydrographs at the upstream and downstream ends of channel reaches for runoff events with no tributary inflow. Transmission losses of 30 acre-feet per mile of channel have been observed during a moderate sized flow; and, owing to the much greater width of channel covered as well as longer flow duration, much higher absorption per mile of channel may be expected from higher flows. The disposition of these transmission losses becomes a very important consideration in evaluating the total water yield of watersheds such as Walnut Gulch.



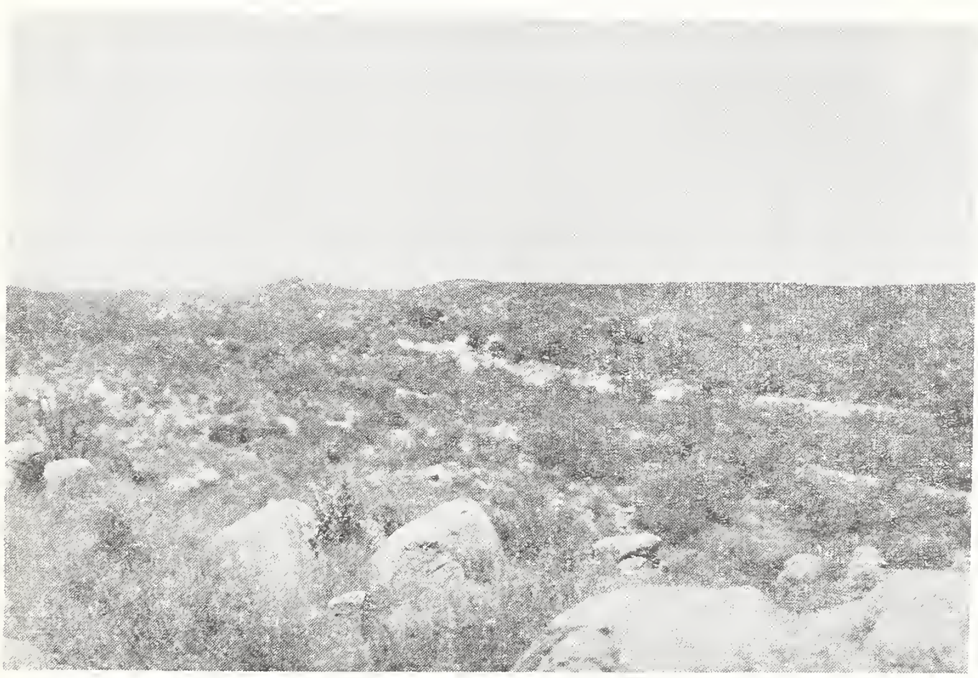
Transmission losses for this flow event reduced the volume of runoff at Flume 6 by 57 percent. In the 6.8-mile reach of channel between Flume 6 and the watershed outlet, the transmission losses of 6.2 acre-feet per mile for this event are considerably less than that which might be expected as a maximum.

Depths to ground water in the watershed vary greatly -- from 150 feet at the lower portion to more than 400 feet in the central areas. Small local water tables, perched at depths up to 35 feet, occur in a few places along the channel system of Walnut Gulch, being controlled by local geologic conditions. Soil moisture penetration has not been observed to depths greater than five feet except in the channels. Recent studies indicate very little recharge to ground water from the upper reaches of the watershed. In the lower reaches, however, channel absorption does contribute to the regional water table.

When geologic conditions are favorable and the channel bed is saturated from previous flows, some of the transmission loss water percolates downward and causes a temporary mounding on the underlying regional water table. This condition occurs typically in the latter part of the summer toward the end of the flow season. The mounding rapidly dissipates after the flow season, leaving a slight net rise in the regional water table level. With continued study of this mounding effect, we may find that this source of recharge is significant.

The small local aquifers adjacent to the stream channels owe their existence to impervious material underlying the channel. The quick response of the water level to flows in the stream channel leads to the conclusion that a portion of the transmission loss water contributes to these aquifers. Water level records from wells in one such aquifer show that the rate of decline is four times as great during the growing season as it is when the vegetation is dormant. Thus, a considerable proportion of the water detained in this aquifer is dissipated by transpiration of the phreatophytic vegetation.

Intensive research is under way on one of these local water tables to determine what happens to the entrapped water; i.e., how much is removed by the plants, how much is dissipated by direct evaporation, and whether any water reaches the regional water table. Both heat budget and water balance methods are being used in this work.



Dense mesquite growth defines limits of local aquifer lying beneath the stream channel. Transmission loss water is stored in the aquifer, and much of it is removed by the vegetation during the growth season.

SEDIMENT STUDIES

The processes of sediment production, transport, and deposition in ephemeral stream channels are being studied at several places on the watershed. Sediment samples are collected from unit source areas of varying size, as well as at Flume Number 1 and 6 on the main channel.

Small flows in the main channel are sampled by wading, using depth-integrated hand sampling equipment; from large flows, samples are collected from cableways, using depth-integrating samplers. Experimental automatic sampling equipment is tested at Flume Number 6 to observe the performance of the equipment in ephemeral streams. Several designs have been tested here for the Federal Inter-Agency Sedimentation Project and have been found to operate satisfactorily for the heavy sediment loads normally observed.

An automatic sediment sampler is seen alongside of a scientist collecting depth-integrated samples by wading the stream.

Channel transmission losses have been observed to have a significant effect on sediment transport. As storm flows are diminished by transmission losses in moving through the channel system, the concentration of their sediment loads increases, and deposition takes place. The more numerous small flows deposit sediments, some of which are later picked up and moved downstream by the less frequent larger flows. This stepwise movement of sediments in ephemeral streams causes difficult problems of relating the sediment concentration to a given water discharge. The sediment "rating curve" has been found to be proportional to six independent variables which affect the various particle-size amounts uniquely. These variables relate the concentration to the water discharge, distance of dry streambed traversed, antecedent moisture of the channel alluvium, elapsed time since the beginning of the storm and the range cover erodibility in the storm area.

Sediment samples collected in the field are processed in the laboratory to determine relative proportions of sand, silt, and clay size particles.

The information furnished by the sediment sampling program should enable our scientists to relate on-site sediment production and movement to that from progressively larger areas and to extend these relationships as they are affected by characteristics of climate, topography, geology, and vegetation, to sediment yield and transport on semiarid watersheds throughout the Southwest.

SUMMARY

The basic information collected in the various phases of the work of the Southwest Watershed Research Center will contribute to a more comprehensive understanding of the many interacting factors affecting land use, sediment production and movement, and water yield, and to an intelligent synthesis of these factors as they affect the use of vast areas of semiarid rangeland in the Southwestern United States.

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